Technical Report Number 3

RESULTS OF THE SOLAR RADIATION PROJECT

of the

RONNE ANTARCTIC RESEARCH EXPEDITION

under contract with

GEOPHYSICS BRANCH
PHYSICAL SCIENCES DIVISION

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FOREWORD

Submitted herewith is the third technical report made by the Ronne Antarctic Research Expedition under contract with the Geophysics Branch of ONR. The material gathered in this "Results of the Solar Radiation Project" is the first compilation of instrumentally measured insolation data taken in any polar region.

W. H. Leahy
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Assistant Chief for Research

1 October 1948

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PREFACE

Technical Report Number 3, prepared by H.-C. Peterson, physicist, is the third in a series of reports on certain technical projects carried out by members of the Ronne Antarctic Research Expedition during 1947 - 1948.

In this report the operation and results of the solar radiation project are discussed. Total horizontal incidence sky and solar radiation was measured primarily for climatological purposes by the Expedition at Stonington Island, Marguerite Bay, Palmer Peninsula, Antarctica, 68°12′S-67° 00′W during summertime from October 1947 to February 1948 using Eppley pattern pyrheliometers and a recording microammeter.

When the project was being planned, difficulty was experienced in procuring equipment, and thanks should be extended to the Eppley Laboratory for its loan of a pyrheliometer, the Blue Hill (Massachusetts) Observatory for the loan of a recording microammeter, and the Charles Englehard Company for its loan of certain parts and supplies needed for the recorder. In writing up results, Mr. Sigmund Fritz, of the Weather Bureau's Physical Meteorology section, offered many helpful suggestions.

The solar radiation investigations are part of the general scientific program carried out by the Expedition and sponsored by the Geophysics Branch, Office of Naval Research.

Finn Ronne

COMMANDER FINN RONNE,
USNR (inactive)
Expedition Leader

SCOPE OF OBSERVATIONS

Total horizontal incidence sky and solar radiation was measured for a five months' period centered around the southern hemisphere summer solstice at a station a few degrees south of the Antarctic Circle.

LOCATION

Description of Region

Observations were made at the main base of the Ronne Antarctic Research Expedition, Stonington Island, Marguerite Bay, Palmer Peninsula, Antarctica, 68°12'S-67° 00'W, elevation of pyrheliometer approximately 50 ft above mean sea level. The island is situated in a small bay nearly surrounded by glacier-clad mountains from 2000 to 6000 ft high. During the period in which insolation measurements were made, the bay was ice and snow covered with the exception of a few tide cracks for at least 6 miles around the island. At more remote distances there were stretches of open water between pack-ice. To the north of the base lay a glacier which subtended an angle of approximately 5° at the site of the receiver. A small bay and terminal glacier was located in the eastern foreground and, in the eastern background about 10 miles away, lay a 4000 ft high plateau fringe. In the south were mountains with frequent rock exposures whose peaks subtended from 1-2° of arc. Our closest mountain, Neny Island, was situated in the southwest and subtended an angle of 10°. Over the bay to the west there were no obstructions.

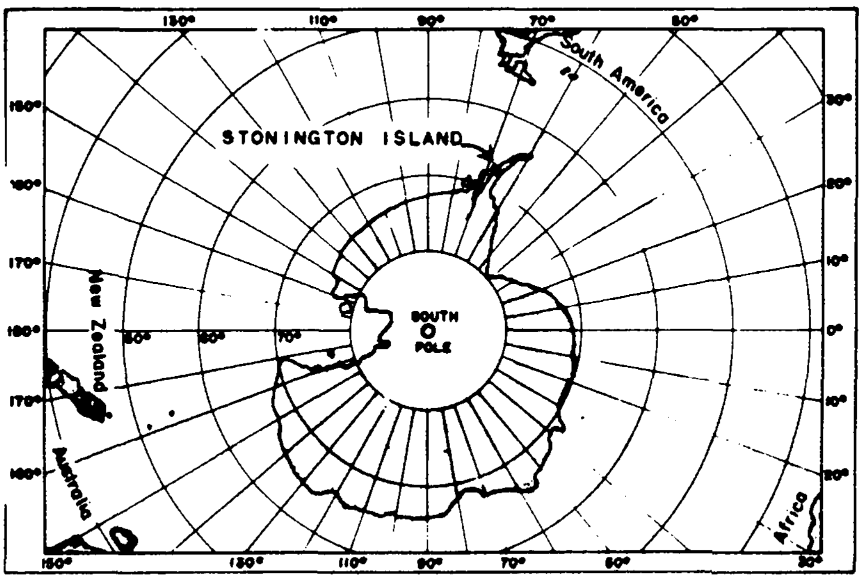

Fig. 1. Map showing general location of Stonington Island

Prevailing summer winds were from seaward and brought in much stratus cloud. In addition, the terrain was highly conducive to orographic cloud development (Table 1). Monthly temperature averages during the period of insolation measurements were subfreezing (Table 1). It is believed that the values obtained are representative of summer insolation on the Marguerite Bay coast of Palmer Peninsula. It is estimated that approximately 5% of the hemispherical area of the sky was cut out by terrain. At 68°12 S the sun reached a noon altitude of 45.3° at the summer solstice and at midnight the sun was 1.8° above the horizon. During the period 1 December 1947 to 12 January 1948, the midnight sun was above the horizon.

TABLE 1

Stonington Island Temperature & Cloudiness

Month	Average Temperature in °F	Mean Total Cloudiness (scale 0-10)
OCT	17.6	8.3
NOV	24.8	8.4
DEC	29.6	5.6
JAN	31.6	7.8
FEB	28.7	8.2

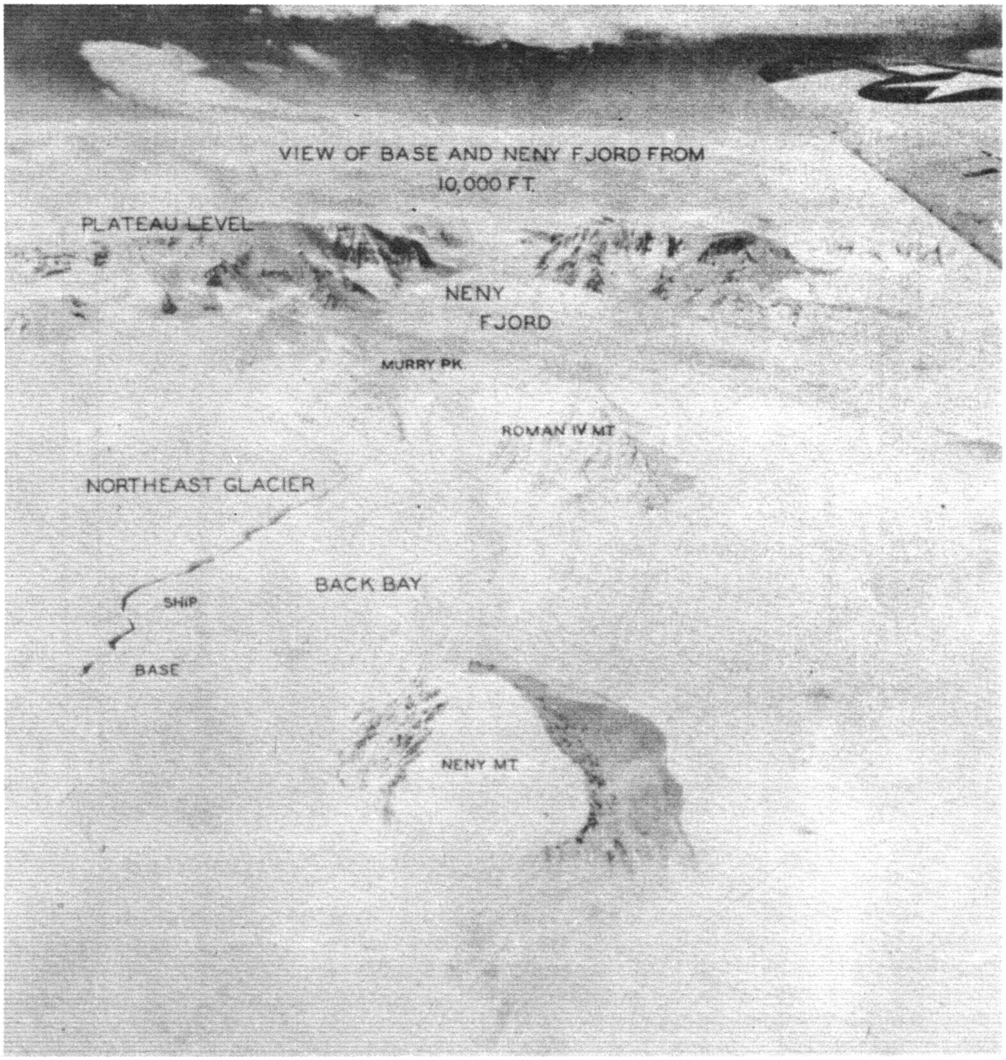

Fig. 2. Aerial photo showing snow surfaces surrounding Stonington Island during summertime 1947-48

INSTALLATION OF EQUIPMENT

The pyrheliometer was mounted atop a meteorological instrument shelter and connected by a 250 ft cable leading to a recorder mounted inside a heated building. This arrangement was decided upon on the basis of accessibility for inspection and adjustments, availability of trained personnel and repair facilities, firmness of recorder mounting and constancy of recorder temperature, and because it was felt that the island site was typical of a location likely to be selected for occupancy by any group operating in this region of Antarctica.

DURATION OF OBSERVATIONS

Observations were begun on 6 October 1947 and, with some interruptions caused by equipment failures, extended to 20 February 1948. No measurements were taken between 22 November 1947 and 5 December 1947 because of a broken pyrheliometer; or on 10 January 1948 because of power failure.

EQUIPMENT

Pyrheliometers

Measurements were begun using an Eppley-built 50-junction pyrheliometer obtained on loan from the Eppley laboratories. On 22 November 1947 the door of the meteorological instrument shelter on top of which the pyrheliometer was placed was violently closed and the shock transmitted to the pyrheliometer caused the glass pedestal upon which the receiving surface was mounted to snap. In order to effect repairs the special glass bulb had to be cut open, giving access to the receiving surface. One of the delicate thermocouple leads was severed internally and after taking apart the receiving element, it was decided that the size of the thermocouple wire on the Eppley-built pyrheliometer was too small to work with using instruments available at the Antarctic base. Therefore the considerably more difficult and somewhat discouraging alternative of making a completely new receiving element of larger dimensions and using larger thermocouple wire had to be resorted to. (See Fig. 3.)

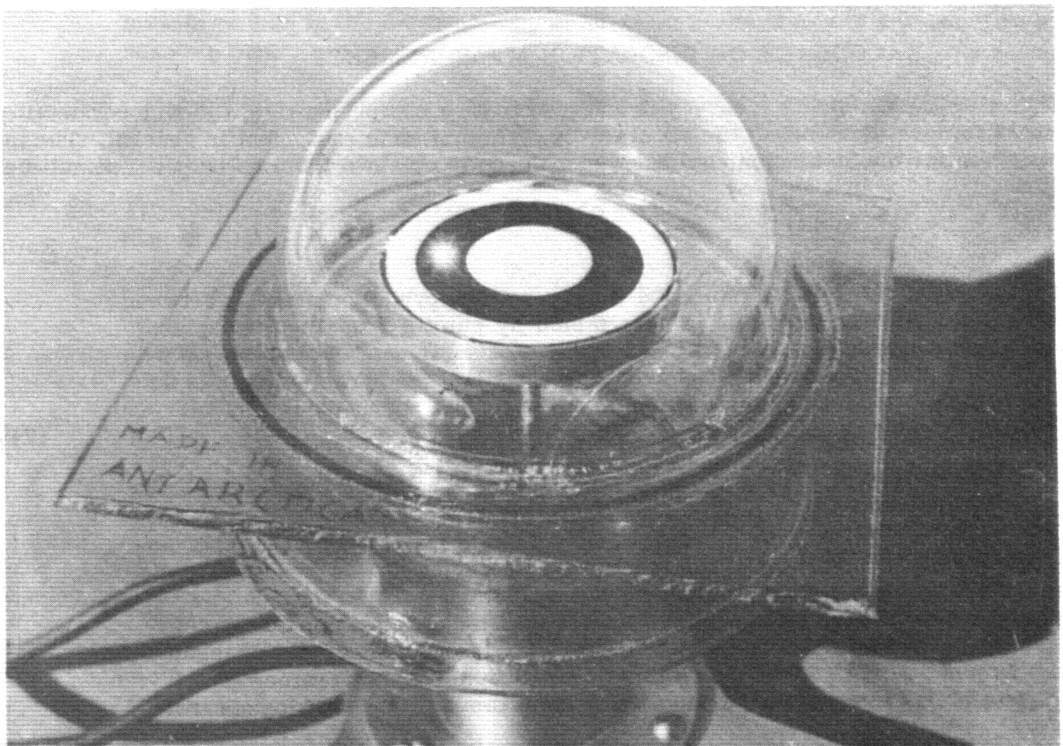

Fig. 3. Photo of Antarctic-made pyrheliometer

Annular disks were filed from sheet aluminum, pedestal was turned from aluminum stock, and thermocouples were made from iron and constantan fastened together under a carbon arc. It was fortunate that suitable thermocouple wire was available from the University of Chicago dewpoint indicator spares. The thermocouple junctions were fastened on the back of the annular disks with black thermoplastic taken from the tops of flashlight batteries. Before a good hold was obtained, considerable material had to be used, thus undesirably increasing the thermal inertia of the receiver. Recently, polyethylene phythalate resin "sagerite" was found by the Bureau of Standards to have one of the highest ratios of electrical insulation to thermal conductivity, but this material was not available on the Expedition. Lamp black in alcohol was applied for the black disk; ground chalk in alcohol was applied on a white paint base for the white disk. The disks were held in the pedestal with small acetate bridges between the pedestal and the outer and inner rings. Junction between thermocouple wire and copper leads is in the base of the pyrheliometer. Resistance of pyrheliometer is 6.2 ohms. The special glass bulb was secured to the old base with a frame constructed of sheet acetate. This acetate, however, warped and the resulting stress caused a small crack in the bulb. The crack was so oriented as to cause no shadow to fall on the receiver. Rubber cement was then used as a moulding between glass and acetate. A small paper capsule of calcium chloride was then internally added to absorb moisture as some trouble was experienced with internal condensation.

The original Eppley-built pyrheliometer was accompanied by a certificate of calibration. The Antarctic-made pyrheliometer was taken to the Eppley Laboratories upon return to the States and a calibration determined. Its sensitivity was approximately that of the original pyrheliometer.

RECORDER

An Englehard recording microammeter was used in conjunction with the pyrheliometer. Before the recorder was used in the Antarctic, the electric clock was replaced with a spring driven clock; and the 110 v printing magnet, with one designed for battery operation. On 10 October 1947, the original galvanometer suspension was found to be in a broken condition and replacement was made from equipment spares with only a few hours loss of record. At the conclusion of the Expedition the recorder was taken to the Eppley Laboratories and a determination of galvanometer and supplementary resistance was made as well as a determination of galvanometer sensitivity for several scale values.

ACCURACY OF INSOLATION MEASUREMENTS

The following discussion on accuracy is intended to be a comprehensive, although not detailedly investigated, list of factors which affect the accuracy of pyrheliometric equipment in general. The magnitudes or error given for the Stonington equipment were usually obtained from estimation, sometimes from computation.

Pyrheliometer	Error
1. The frequency response of standard Eppley-pattern pyrheliometers is between 2900 and 25000 Ångstrom units determined by cutoffs from the atmosphere and glass cover, respectively.[1] The relation of solar energy distribution with respect to the frequency response characteristic of the pyrheliometer is not known with great accuracy and probably changes in a poorly-known manner with the condition of the atmosphere.	(?)%
2. The sensitivity of the pyrheliometer as a function of ambient temperature was found by a National Bureau of Standards test on several Eppley pyrheliometers to vary from .05% to .11% per degree C.[2] This is mainly due to the thermoelectric voltage generated at the junction of the copper lead wires and the dissimilar thermocouple wires of the receiving element. This effect can be eliminated if the base of the pyrheliometer, in which the lead junctions are located, is held at a constant temperature. Increasing the number of thermocouple junctions in the receiver minimizes the ambient temperature effect. Other ambient temperature errors arise from the fact that heat losses from	

[1] I. F. Hand: "Pyrheliometers and Pyrheliometric Measurements," U.S. Dept. of Commerce, Weather Bureau, Wash., D. C., Nov. 1946.

[2] N.B.S., No. IV-5/Tp: 451z-17/46, dated 10 May 1946.

the black ring of receiving unit are an exponential function of the absolute temperature. The sensitivity of the pyrheliometer is reduced at high ambient temperatures: The heat loss from the black ring is greater, the black ring is cooled more than usual, the difference of temperature between the black and white rings is less, and the response is less. A third error in trying to measure temperature differences over a wide range of ambient temperatures arises from non-linearity of thermocouple voltage versus temperature characteristic. Thus as the slope of the temperature voltage curve changes over a range of ambient temperatures, the difference in thermocouple voltage for any fixed difference in temperature would vary. It is the understanding of the author that these ambient temperature errors are small compared to the effect produced by the thermocouple voltage at the junction of the copper leads and the receiving unit. (?)%

3. The receiver was investigated in the above test[3] for a deviation from true sinusoidal response and it was found that the sensitivity increased as much as 15% above a sinusoidal characteristic at angles of incidence of 10° and less. Cause of this effect is a variation in the reflecting power of the surface with angle of incidence, there being greater reflection as the radiation approaches grazing incidence. For example, Shaw cites[4] that only 2% of radiation is reflected from water at angles of incidence of 47° while 71% is reflected at angles of incidence of 5-1/2°. However, the high values of radiation at noon greatly minimize this correction for low altitude. Some correction of values was made.
   Monthly error: 1%
   Clear day error: 0%

4. In the Antarctic-made pyrheliometer particular attention was paid to horizontalness of the receiving surface. This was determined by the run of a drop of water on the receiving surface. However, a nonuniform application of the black and white coating could, in effect, alter the horizontalness. 1%

5. The deterioration of the black and white surfaces of the pyrheliometer between measurements in the Antarctic and calibration in the states is a possibility of unknown magnitude. -(?)%

6. In all pyrheliometers there is a possibility of erroneously high sensitivity due to internal reflection. There is little reason to believe that this effect was higher than usual in the Antarctic-made pyrheliometer. -(?)%

7. The response-lag of the Antarctic-made pyrheliometer was only slightly greater than usual. 0%

8. Initial and constant transparency of the pyrheliometer glass bulb was believed to be good as there was a minimum of atmospheric polution. However, on days with precipitation or frost there would be appreciable periods in the day when snow or ice would remain unremoved. This introduces no error on clear days and some error on a monthly basis.
   Monthly error: 3%
   Clear day error: 0%

9. The accuracy of standard pyrheliometers has been questioned, but the order of magnitude of possible error for our measurements is probably negligible. 0%

Leads

Temperature or conductor elongation effects on resistance and extraneous voltages introduced by such causes as thermal gradients (Thompson effect), junctions (thermocouple effect), or rectification of stray alternating current fields were observed to be negligible. 0%

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[3] No. IV-5/Tp: 451z-17/46, dated 10 May 1946

[4] W. N. Shaw, Manual of Meteorology, Vol. 3, 1942, Cambridge, p. 144.

Supplementary Resistances		Error
1. Determination of value of resistance.		.5%
2. Temperature effect on resistivity (assumed).		0%
Galvanometer		
1. Determination of sensitivity.		.5%
2. Nonlinearity of response.		1%
3. Zero error.		1%
4. Temperature effect on resistivity (beyond corrections applied).		.5%
5. Ageing and temperature effects on sensitivity.		(?)%
Reduction of Chart Values		
1. Obtaining mean hourly values.	Monthly error:	2%
	Clear day error:	0%
Total Error:		
Arithmetical sum	Monthly:	10.5%
	Clear day:	4.5%
R.M.S. sum	Monthly:	4.2%
	Clear day:	1.9%

This order of accuracy is far from satisfying.

Recent models of electronic recorders measured voltage, not current and thus eliminate all resistance errors. Also the latest model recorders have a high degree of accuracy and because of a linear scale make possible the integration of chart values by planimeter.

However, the errors in the pyrheliometer itself remain incompletely investigated.

RESULTS

The reader is cautioned that the insolation values presented for Stonington Island are actual values measured on top of the snow surface and contain a component of radiation that is dependent upon snow reflection. For example, on clear days at noon during the summer solstice horizontal incidence total sky and solar radiation was received at the rate of approximately 81 kilowatts per square dekameter. A portion of this power is due to radiation reflected skyward from the snow surface which in turn is reflected by the atmosphere earthward. Thus, if an extensive heat absorbing surface were to replace the snow surface, the values of insolation measured would be less.

In this report Insolation is used to mean the rate (power) or amount (energy) of horizontal incidence total sky and solar radiation falling upon a point just above the surface of the earth at the location of the pyrheliometer.

In Table 2 are presented values of total daily horizontal incidence total sky and solar radiation received at Stonington Island, Antarctica, during 1947 and 1948. Weekly averages and monthly averages and extremes are given.

In Table 3 are presented mean hourly horizontal incidence total sky and solar radiation intensities (power) during the calendar month before and the month after the summer solstice at Stonington Island, Antarctica, and Fairbanks, Alaska.

For climatic comparison purposes Fig. 4 illustrates monthly average insolation at Stonington Island, Fairbanks, and at the top of the atmosphere over Stonington Island. Stonington Island data were plotted from the monthly averages given in Table 2 of this report. Fairbanks data were obtained from weather bureau station records of the years 1940 and 1942. The values of insolation at the top of the atmosphere were interpolated from Milankovitch's computations which appeared in Handbuch der Klimatologie by W. Koppen and R. Geiger, Page A14, Table 1, "Die Taglichen Strahlungsmengen bei Alswesenheit der Atmosphare."

Average hourly values of horizontal incidence total sky and solar radiation intensity (power) received at Stonington Island for the months of December and January combined are illustrated with similar data for Fairbanks in Fig. 5. Data were obtained from Table 3 of this report.

Fig. 6 shows a 24-hour period of an actual insolation chart recorded at Stonington Island. 29 December 1947 was a clear day until 2240 GMT when a few altocumulus associated with altostratus clouds intervened. Notice the sharp cutoffs of solar radiation as the midnight sun passed between mountain peaks to the southeast.

TABLE 2

DAILY TOTAL INSOLATION AT STONINGTON ISLAND, ANTARCTICA

MONTH	INCLUSIVE DATES	DAILY TOTAL ENERGY IN G-CAL/CM^2			
		WEEKLY AVERAGE	MONTHLY AVERAGE	MONTHLY MAXIMUM	MONTHLY MINIMUM
OCT	1-7	300			
	8-14	304			
	15-21	284			
	22-28	404			
	29-4	456			
			350	647	167
NOV	5-11	527			
	12-18	544			
	19-25	705			
	26-2	[625]			
			586	900	430
DEC	3-9	775			
	10-16	612			
	17-23	704			
	24-30	680			
			680	828	398
JAN	1-7	615			
	8-14	575			
	15-21	447			
	22-28	567			
			551	743	275
FEB	29-4	411			
	5-11	328			
	12-18	304			
			368	547	173

[ ]Value enclosed in brackets was interpolated
Conversion factor: 1 g-cal/cm^2 = 1.16 kwh/(10m)^2

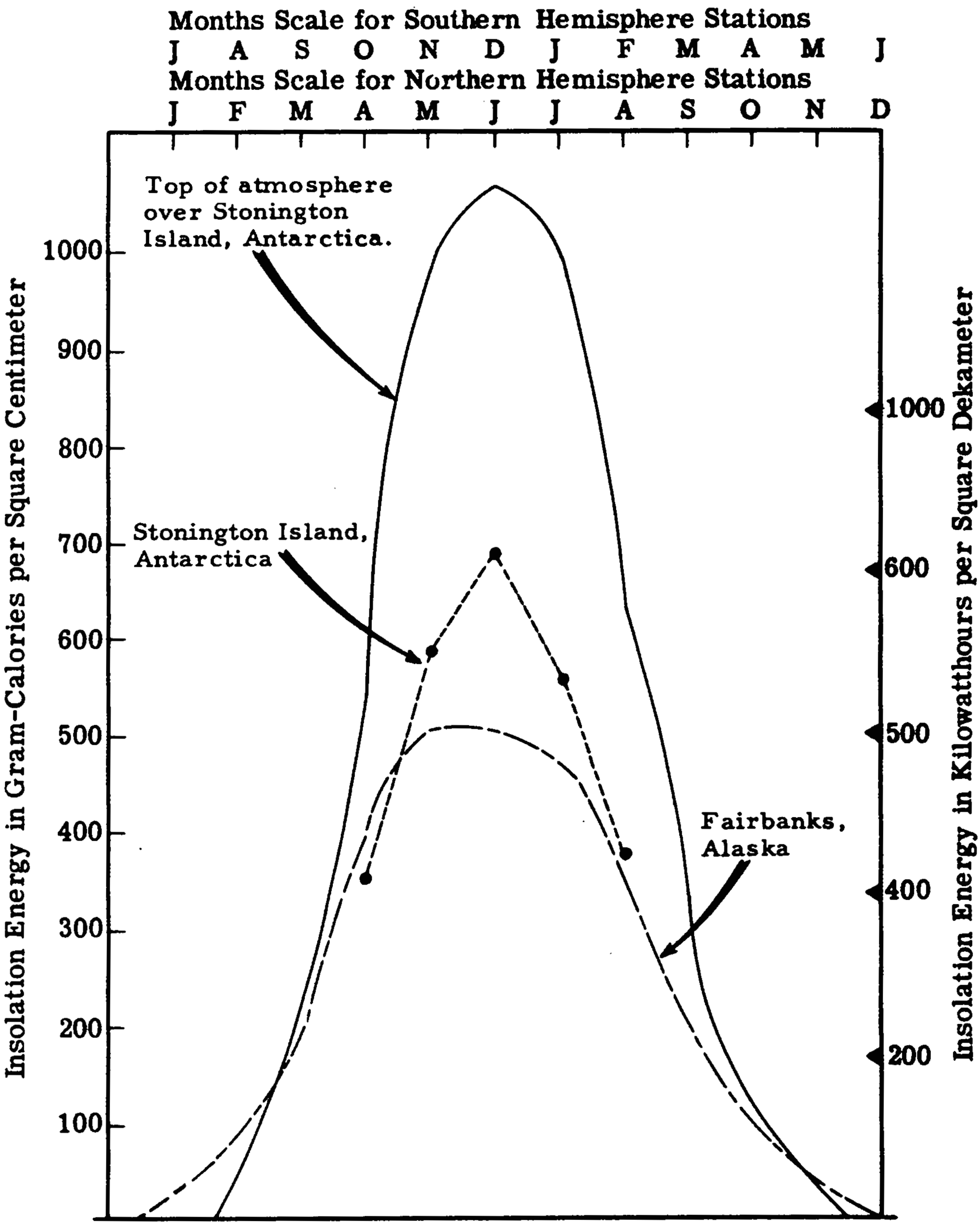


Fig. 4. Monthly mean values of daily horizontal incidence total sky and solar radiation energy at Stonington Island, Antarctica; Fairbanks, Alaska and at the top of the atmosphere over Stonington Island, Antarctica.

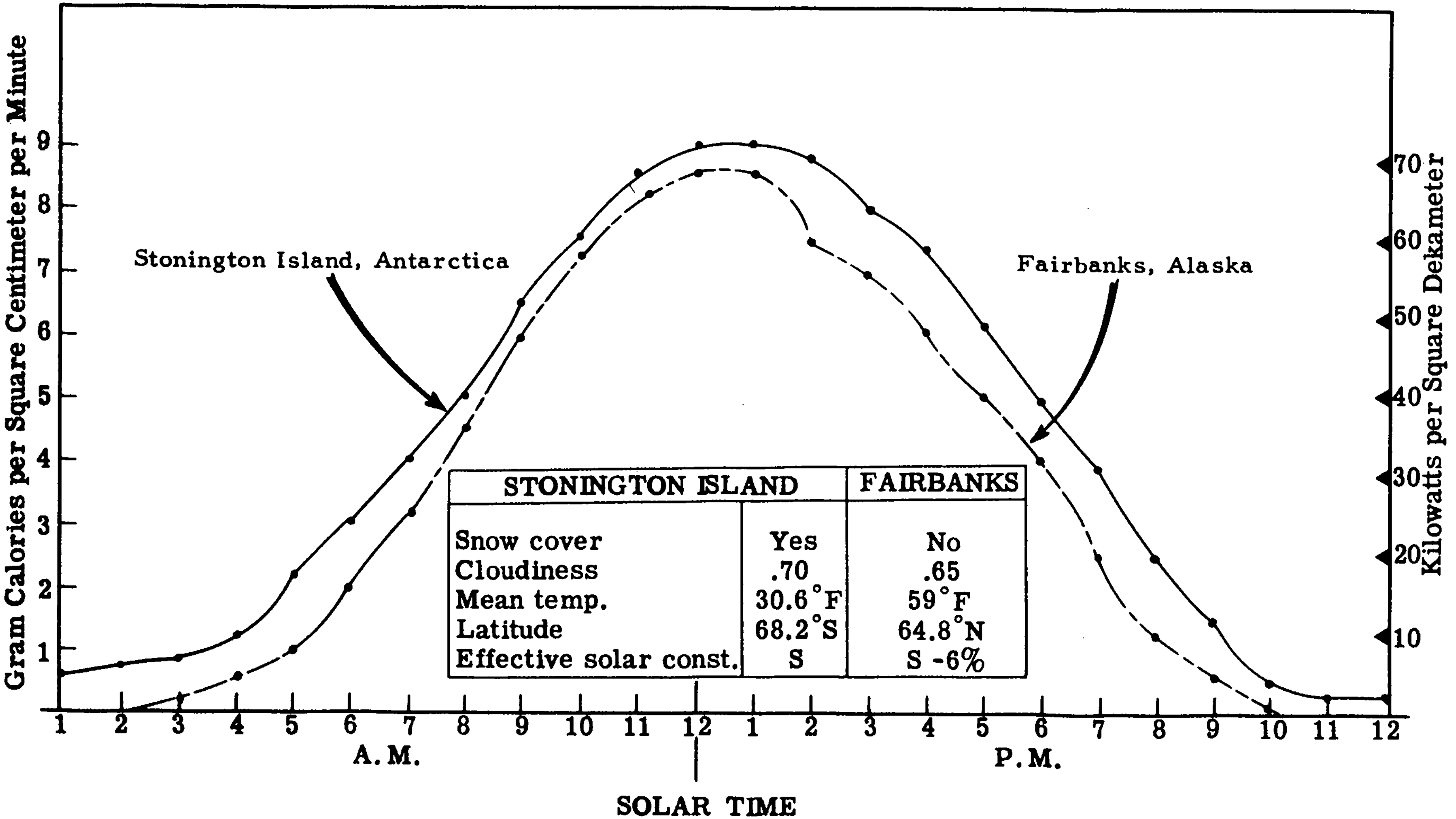
TABLE 3

SUMMERTIME HOURLY INSOLATION VALUES FOR STONINGTON ISLAND, ANTARCTICA AND FAIRBANKS, ALASKA

SOLAR HOUR	INTENSITY(POWER) IN GRAM-CALORIES PER SQUARE CENTIMETER PER MINUTE	
	STONINGTON ISLAND, DECEMBER AND JANUARY 1947-8	FAIRBANKS, JUNE AND JULY 1942
1 AM	.04	.00
2 AM	.05	.00
3 AM	.07	.01
4 AM	.12	.04
5 AM	.19	.10
6 AM	.28	.20
7 AM	.39	.33
8 AM	.50	.46
9 AM	.65	.60
10 AM	.76	.73
11 AM	.84	.84
NOON	.90	.85
1 PM	.91	.85
2 PM	.89	.74
3 PM	.83	.70
4 PM	.73	.66
5 PM	.61	.49
6 PM	.48	.38
7 PM	.39	.24
8 PM	.25	.12
9 PM	.14	.06
10 PM	.07	.02
11 PM	.04	.00
MIDNIGHT	.04	.00

Conversion factor: 1 g-cal/cm^2/min = 69.7 kw/ (10m)^2

Fig. 5. Mean hourly horizontal incidence total sky and solar radiation intensities (power) during calendar month before and month after summer solstice at Stonington Island, Antarctica and Fairbanks, Alaska.



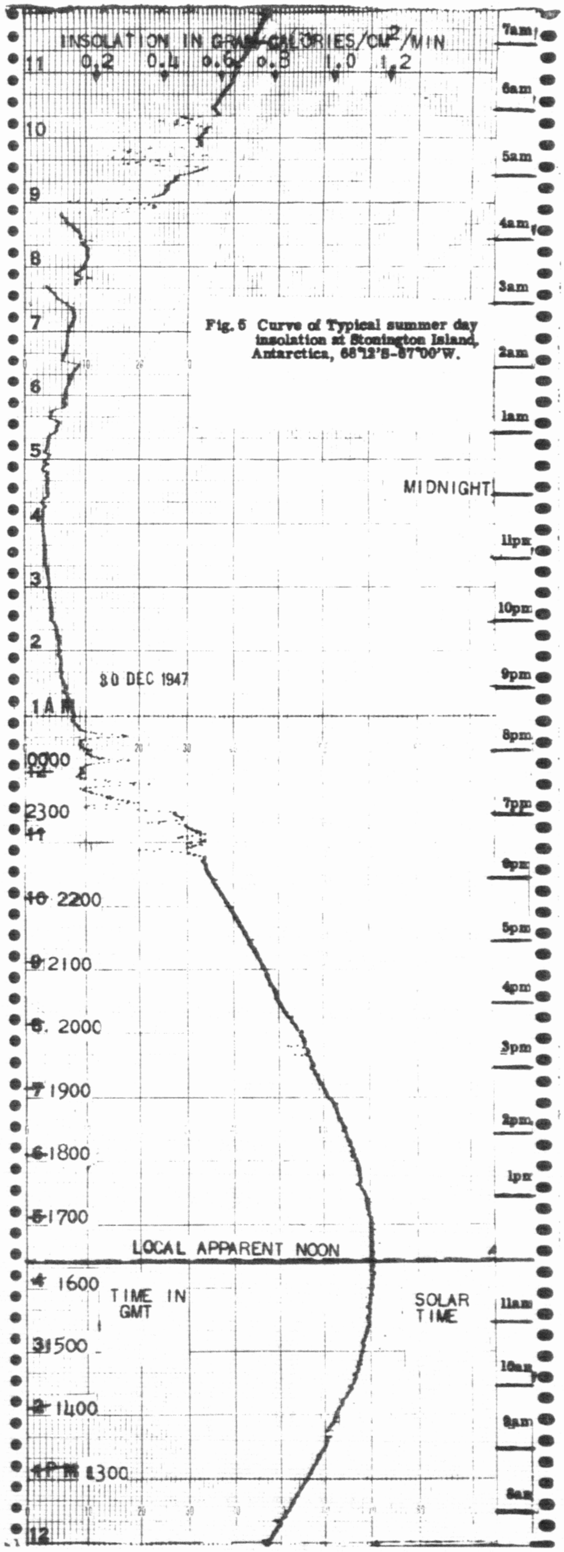


Fig. 6. Curve of typical summer insolation at Stonington Island

DISCUSSION

Agreement of Measured and Theoretical Insolation Values

In an effort to better view some of the factors affecting solar radiation at our Antarctic station, values of insolation will be computed from theoretical considerations and checked for agreement with the actual measured insolation. The comparison will be made for horizontal incidence total sky and solar radiation received at noon on clear days near the summer solstice. The radiation unit used will be a measure of intensity (power), gram-cal/cm^2/min. The horizontal incidence total sky and solar radiation at the earth's surface can be given by:

$$R = A + B + C \qquad \text{Eq. (1)}$$

Where: A is the direct radiation arriving at the earth from the sun only.

B is the diffused radiation from the sky due to atmospheric scattering of the sun's rays.

C is the diffused radiation from the sky due to a scattering of radiation reflected skyward from the earth's surfaces.

A can be given by: $A = KS \sin H$, Eq. (2)

Where: K is the atmospheric transmission

S is the effective solar constant

H is the sun's angular height above the horizon

The factor K, atmospheric transmission, is a function of atmospheric content of water vapor and other gases, the obliquity of the sun's rays (air mass), and the frequency of radiation. After many simplifying assumptions are made, K is given in a chart in the Smithsonian Meteorological tables[5]. (3)

S, the effective solar constant, is a function of the mean solar constant (equal to 1.94 units) and the distance between the sun and the earth, a distance which varies slightly between seasons of the year. S is very nearly 2 units in December while in June it is about 1.9 units.

H is the sun's angular height above the horizon and, at noon, from considerations of elementary astronomy, is equal to the station latitude--90° + the sun's declination. (4)

B is a difficult value to arrive at, but was approximated to be 10% from Kimbal's observations which are in part reproduced here:[6]

TABLE 4

SKY RADIATION AS A PERCENTAGE OF TOTAL RADIATION

STATION	SOLAR ALTITUDE				
	65°	41.7°	30°	19.3°	11.3°
Washington, D. C.					
Winter	-	12	16	23	37
Summer	19	21	24	31	40
Lincoln, Neb.	15	16	19	24	36
Madison, Wis.	16	16	24	26	-

(5)

It was assumed that in the determination of these values the reflection of the earth's surface was generally low compared to a completely snow covered surface, at least less than 20%.

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[5]1939 Edition, p. lxxiv, Fig. 1.

[6]Monthly Weather Review, Vol. IV, p. 156, 1927.

C is an uninvestigated value which can only be roughly approximated. In a collimated beam directed through the atmosphere, approximately 80% of the beam energy succeeds in penetrating the atmosphere, while 20% is lost due to scattering.[7] In the case of a diffuse beam the effective path length may be twice as long. Therefore, by Beer's exponential law of radiation transmission, the transmission is $(80\%)^2$ or 64%; while accordingly, 36% must be lost due to scattering. Of all this scattered energy, approximately 50% is directed downward. This means that 50% of 36%, or 18% of the reflected radiation energy returns downward. This process repeats itself in an infinite series and is dependent upon the reflectivity of the earth. For snow cover reflectivities of 50% this repetition of reflection would bring the total diffuse sky radiation due to reflection from the earth to about 20% of the reflected radiation. Thus, if D indicates the amount of total sky and solar radiation reflected into the sky from the earth, then:

$$C = .2D \text{ (roughly)} \qquad \text{Eq. (6)}$$

Values of insolation expected at Stonington Island are now computed for clear days at noon near the summer solstice.

On the Antarctic summer solstice the sun's declination is 23.4° (from the Nautical Almanac).

By (4) this gives a solar height at noon of 45.2° for our station at latitude 68.2°S.

The effective solar constant is 2.0 during December.

K, the atmospheric transmission, is obtained by chart (3). The amount of precipitable water in the atmosphere is assumed to be 0.9 cm which, according to the formula given in the Smithsonian Meteorological tables in the discussion of chart (3), corresponds to a vapor pressure of 4 mm at 30°F. The air mass through which the sun's rays of height 45.2° have to pass is equal to 1/sin 45.2° or 1.4 times the air mass through the zenith. We then set on chart (3) with arguments precipitable water 0.9 cm and air mass 1.4. The atmospheric transmission indicated by the chart (3) is 77%.

Then, by equation (2), $A = .77 \times 2 \times \sin 45.2° = 1.09$ units.

B is 10% of the total radiation R assuming C to be negligible; thus $R = A + .10(R)$, whence B which by (5) is approximated to be 10% of R, has a value of .12 units, approximately.

In computing C, a snow reflection of .5 is assumed to be representative of the generally complete snow cover on Stonington Island. At this stage of the computation 1.09 + .12 or 1.21 units impinge upon Stonington Island and .5 x 1.21 or .60 units are reflected. By (6), $C = .2 \times .60$ or .12 units.

Thus, $R = 1.09 + .12 + .12 = 1.33$ units.

The actual value measured was 1.17 units. The discrepancy is 11.4% above measured values.

As a check of the theoretical method used in computing Stonington Island insolation values, horizontal incidence total sky and solar radiation will be computed for clear days at noon during the summer solstice at Fairbanks, Alaska:

> The sun's height at the summer solstice at Fairbanks (64.8°N) is 45.5°. S, the effective solar constant, is about 1.9 during June, the month of the northern hemisphere summer solstice. Using (3), K, the atmospheric transmission, is determined by precipitable water of 2.0 cm [corresponding to a vapor pressure of 9 mm at dewpoint 50°F] and air mass of 1.34 [or 1/sin 48.5°] to be .72.
>
> So A, by (2) is: $A = .72(1.90)(\sin 48.5°) = 1.03$ units.
>
> In the computation of B, it seems reasonable to use a factor of 15% because of the higher temperature at Fairbanks. This gives B a value of .15 units.

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7 I. F. Hand, "An Approximation from the Transmission data," <u>Monthly Weather Review</u>, Vol. 65, pages 438-439, Dec. 1937.

The snowless summer surface at Fairbanks is considered to reflect only a small amount (less than 15%) of insolation into the sky and as this amount is already contained in the values of B determined in Kimbal's observations, C = O.

Thus at Fairbanks,

$$R = 1.03 + .15 + O = 1.15 \text{ units.}$$

Actual values measured average 1.20 units.

The theoretical computation of insolation seems to agree more closely with the measured values for Fairbanks and, assuming accurate equipment at Fairbanks, this better agreement might imply that the measured Stonington Island values should be increased, perhaps because of a change in instrument sensitivity between the Antarctic and the calibration laboratory in the U. S. However, the direction of the change in sensitivity is contrary to that expected from a deterioration in the receiving surface of the pyrheliometer; therefore the values of insolation at Stonington Island will not be further modified. The discrepancy between theoretical and measured values will be considered in these possibilities:

1. Over-all accuracy of the Stonington Island pyrheliometric equipment.

2. Non-applicability to Stonington Island conditions of the assumptions made in the theoretical computations.

The factors whose error is given by (?) % in the discussion on accuracy should be investigated and might account for a portion of the discrepancy.

If the B and C components of total sky and solar radiation are halved, then the theoretically computed insolation becomes 1.21 units and the discrepancy between measured and theoretical values of insolation becomes a matter of some 3.4% which is quite within the estimated possible error of the measuring equipment.

However, the author is reluctant to reduce B and C as this would probably imply a more transmissive atmosphere, which would in turn increase the A component of insolation.

In view of the many assumptions made in chart (3), the extrapolation of temperate zone conditions for the assumption of B, and the gross assumption in C, the author concludes that the discrepancy between actual and theoretical values is within bounds of the accuracy of the measuring equipment.

Asymmetry of AM and PM Insolation:

With reference to Fig. 5 it appears that the average Stonington Island values of insolation intensity (power) were generally higher in the afternoon than the morning. This asymmetry did not occur in the Fairbanks curve. Possible explanations are:

1. Non-horizontalness of the receiving surface of the Stonington Island pyrheliometer.

2. Different reflectivity of surfaces to AM and PM sun's rays at Stonington Island.

3. Possible diurnal variation in cloudiness at Stonington Island.

None of these factors are accurately known.

Increase in Insolation due to Cloud Reflection:

Fig. 7 shows a section from a Stonington Island insolation recording illustrating a large increase in insolation due to reflection of the sun's rays from a cloud onto the pyrheliometer. This phenomena occurred frequently on partly cloudy days and, on a monthly basis, tends to lessen the mean attenuation of the clouds.

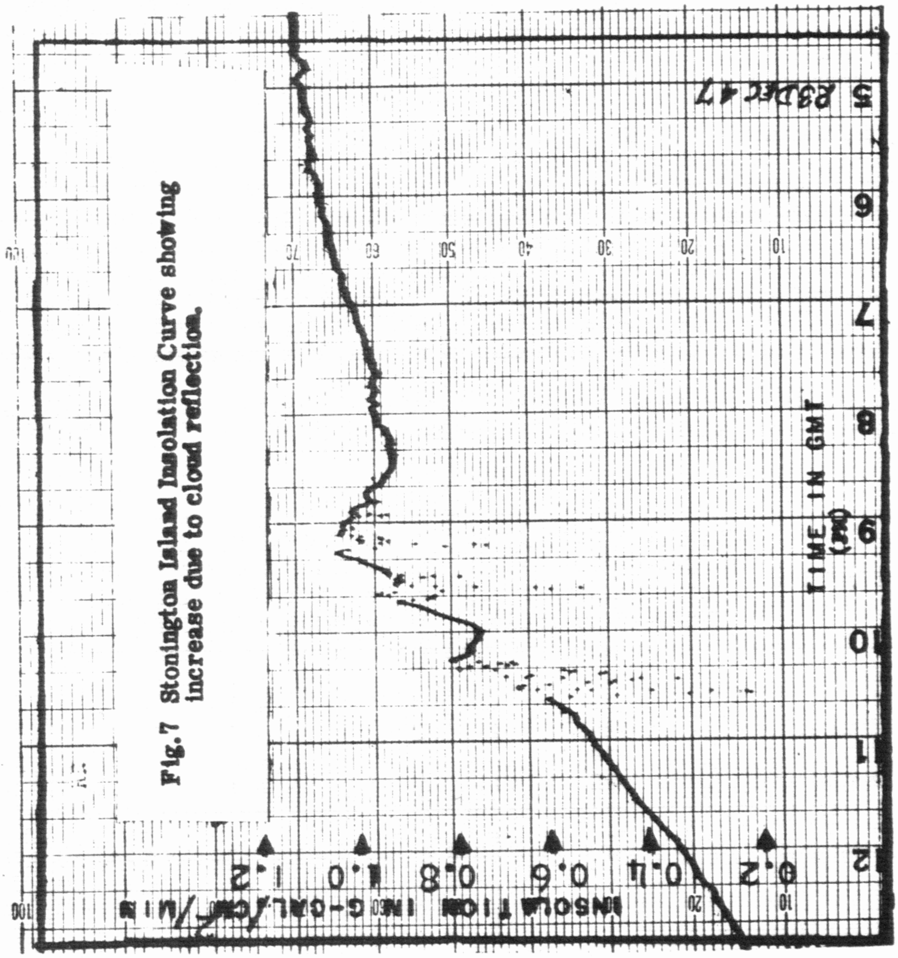

Fig. 7. Section from a Stonington Island Insolation recording showing increase in insolation due to cloud reflection

Transmission of Insolation through an Overcast sky:

While in the Antarctic, the author was surprised at how strong the sun felt through an overcast. Insolation and weather records for the station were investigated and it was found that considerably less attenuation is caused by an overcast sky at Stonington Island than at a station[8] representative of temperate zone climates:

See Table 5 on following page.

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[8] B. Haurwitz, "Insolation in Regard to Cloud Type," Journal of Meteorology, Vol. 5, p. 113, Table 4, June 1948.

TABLE 5

AVERAGE PERCENTAGE OF CLEAR DAY INSOLATION RECEIVED THROUGH AN OVERCAST

STATION	WITH PRECIPITATION	OF LOW CLOUDS	OF MIDDLE CLOUDS	OF HIGH CLOUDS
Stonington Island, Antarctica	63	69	-	-
Blue Hill, Mass., USA[8]	20	30	45	80

Observations were made at solar noon for computational convenience. No separate tabulation was made for the sun's altitude which varied from about 35° to 45° as Hewson[9] has shown theoretically that the insolation reduction by an overcast sky should be practically independent of the sun's altitude and this theory is reasonably well confirmed by Haurwitz's measurements[8]. At Stonington Island 15 observations were made during precipitation overcasts and 16, during low cloud overcasts. Incomplete or complex overcasts prevailed during the remainder of the period of insolation measurements.

It is interesting to note that the minimum insolation transmitted through an overcast at Stonington Island was not under 30% of the clear day value:

TABLE 6

MONTH	MINIMUM PERCENTAGE OF CLEAR DAY RADIATION RECEIVED AT STONINGTON ISLAND	AIR TEMPERATURE AT TIME OF OBSERVATION IN ° F IN EXCESS OF MONTHLY AVERAGE
OCT	46	+14
NOV	53	+ 4
DEC	40	+ 3
JAN	39	+ 5
FEB	30	+ 8

The air temperature data in Table 6 shows that greatest attenuation was caused by warm front air masses.

Application of Insolation Measurements:

Insolation records are recognized of definite agricultural value in indicating on a climatic basis expected sunshine for potential crop areas. However, although the sun is the driving force behind all winds and weather, the author is not aware of any successful applications of insolation measurements to meteorological forecasts, especially at single isolated stations.

Fog versus Insolation:

Although data are not presented in this report, it is felt by the author that for any station, charts or tables could be prepared which, together with an hourly check on insolation values received through a stagnant air mass fog, would greatly assist in predicting the time of dissipation of the fog.

The author feels that further investigation along this line might result in a forecasting technique valuable to aviation.

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[8] B. Haurwitz, "Insolation in Regard to Cloud Type," Journal of Meteorology, Vol. 5, p. 113, Table 4, June 1948.

[9] E. W. Hewson, "The Reflection, Absorption, and Transmission of Solar Radiation by Fog and Cloud," Quart. Jour. R. Meteor. Soc., 69, 47-62, 1943.

CONCLUSIONS

1. Horizontal incidence total sky and solar radiation was measured primarily for climatological purposes at Stonington Island, Marguerite Bay, Antarctica from 6 October 1947 to 20 February 1948 with some interruptions due to equipment failures.

2. It is felt by the author that the subject of errors in pyrheliometric equipment needs further investigation.

3. The values of insolation received at Stonington Island were higher than usual because of radiation reflected skyward from the snow surface being again reflected from the sky earthward.

4. This phenomena of additional insolation from sky due to radiation reflected skyward from snow surfaces, and known to polar mariners as ice blink, has not been investigated quantitatively as far as this author knows. Useful data could result from comparison of insolation values for certain stations when the terrain is snow covered and when the terrain is bare.

5. Cloud attenuation of insolation in the Antarctic is considerably less than in temperate climates. At the Stonington Island station 40-60% of clear day radiation was received through a low cloud or precipitation overcast.

6. The possible application of insolation measurements in forecasting the time of dissipation of stagnant air mass fog should be investigated.